Polymer Performance Research

Polymers are routinely called upon to perform reliably in applications in which they may be exposed to a wide range of environmental stresses. The ability to characterize and monitor their degradation is crucial in determining the service life of components and systems that use these materials. Decisions as to whether to repair, refurbish, or replace parts and components depend on an accurate knowledge of the degraded condition of the polymers from which they are constructed.

The Engineering Mechanics and Infrastructure Group at Brookhaven National Laboratory (BNL) has performed state-of-the-art R&D in polymer science and engineering under the sponsorship of the Department of Energy, the Nuclear Regulatory Commission, and industry. We have simulated the aging of polymers under diverse controlled environmental stresses (e.g., thermal, radiation, chemical, and high-temperature steam) with the objective of analyzing, monitoring, and characterizing their resulting degradation. The technical expertise that BNL has developed allows us to understand the processes and mechanisms that degrade polymers and cause adverse dielectric performance. Research programs include the aging and breakdown of electric cables, nuclear-waste containers, coatings, ion-exchange resins, and low-level radioactive waste forms. The findings from these programs allowed us to develop inexpensive, accurate short-term tests to estimate the useful lifetimes of polymers under normal conditions and in severe accidents.

Materials Examination

Capabilities

- Plan and conduct accelerated aging tests under various combinations of environmental stresses (e.g., thermal, radiation, humidity, vibration, chemical spray, and high voltage).

- Employ a full array of standard and advanced analytic techniques to monitor age-related degradation in insulating properties, including chemical (spectroscopic analysis, oxidation induction time, and temperature), mechanical (elongation-at-break, compressive modules, and hardness), and electrical (time domain reflectometry, insulation resistance, ac impedance), to identify those characteristics most useful for trending polymer degradation in the field and the laboratory.

- Analyze the results of accelerated aging tests together with information extracted from BNL's polymer performance database to develop models for polymer degradation. These models may then be used to predict the performance of a polymer under actual service conditions and to estimate the remaining reliable life of a material operating in a specified environment.

- Analyze and interpret the basic physical and chemical mechanisms of aging degradation in polymers.

- Undertake detailed visual-and dimensional-analysis of polymers to detect, quantify, and monitor aging.

- Design and perform environmental qualification tests of components and systems which utilize polymers.

Major Resources

- Electric Cable Test Facility, a multi-disciplined test laboratory with instrumentation and equipment for characterizing the physical, chemical, and electrical insulating properties of polymers,

and for conducting accelerated aging studies.

- Electric Cable Storage Facility, a controlled-environment stockpile of electric cables representing all the major types of polymer insulations commonly used. The facility includes both new and naturally aged cables removed from nuclear power plants where they had operated under a wide range of documented environments.

- National Synchrotron Light Source (NSLS), producing X-rays, ultraviolet and infrared light that is used to determine the properties of matter, such as surface structure, crystal structure, bonding energies of molecules, chemical-and physical-phase transformations, electronic structure, and magnetic properties.

- Materials Sciences Division Laboratory, with specialized test facilities, instrumentation, and equipment for chemical, physical, and structural studies of materials.

Selected Accomplishments

- Provided technical support to the U.S. Nuclear Regulatory Commission's Environmental Qualification research program on the qualification of low-voltage instrumentation and control cables. This program examined the degradation of polymers over 10 to 60 years of simulated service conditions.

- Completed detailed material analyses on a failure of a high-voltage power cable at a research facility. Recommendations for condition monitoring were identified to prevent recurrences of the problem in replacement cables and similar cables at the facility.

- Performed all polymer research in accordance with the BNL EQ Quality Assurance program, which was audited and accepted as equivalent to 10CFR50 Appendix B programs.

- Designed and compiled a comprehensive PC-based EQ Database which contains citations to both domestic and foreign research on polymers.

Cable Thermal Aging

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